# INTEGRATED WEED MANAGEMENT (IWM)

## Guidelines for Australian Cotton Production

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## IWM is best practice in weed management

### The impact of weeds

Weeds adversely impact cotton in many ways. Weeds compete for nutrients, water and light. They can also directly impact cotton quality through contamination of cotton fibre and seed. Weeds may act as sources of pests or diseases that affect cotton, they may reduce irrigation, cultivation and harvesting efficiency, and they may cause physical injury to operators in cotton fields, such as bug checkers, machinery operators and irrigation staff.

Even a single weed, such as a large fierce thornapple (*Datura ferox*) can compete strongly with cotton. The economic threshold for controlling thornapple by hand-hoeing is less than one plant per 100 m of cotton row, based purely on cotton yield reductions through competition. In addition, thornapples can host Heliothis, mites and verticillium wilt, they can block cultivation and harvesting equipment, and they can cause serious injury to field workers. Thornapple seeds may also contaminate cotton seed.

*Weeds compete strongly with cotton, reduce yields, reduce lint quality, obstruct harvest operations and injure workers. The economic threshold for hand hoeing fierce thornapple is just 1 per 100 mm of cotton.*

Weeds also impact cotton production indirectly, as many of the tools used to manage weeds are expensive and can adversely affect cotton to some extent. Most herbicides cause some degree of leaf or root damage to cotton. Many of the more commonly used residual herbicides can and on occasions do kill cotton plants if they are incorrectly applied, or if adverse weather conditions occur soon after application.

## What is integrated weed management (IWM)?

IWM is about **NOT** relying on only one or two methods of weed control alone, and particularly not relying on a herbicide or a single herbicide group alone. To use a quote from Prof. Stephen Powles, Director of the Australian Herbicide Resistance Initiative, "When you are on a good thing, don't stick to it!"

An IWM program uses a range of weed control tools in combination so that all weeds are controlled by at least one component of the weed management system. IWM also recognises and incorporates as far as possible, the other aspects of crop production, all of which have some effect on crop and weed growth. Some of these effects may be small, but they can combine to make an important difference to both crop and weeds.

Ultimately, the aim of IWM is to prevent weeds setting seeds, or vegetatively reproducing, so that the weed population is reduced over time, reducing weed competition and improving crop productivity. This aim must apply to all phases of the cropping phase, not just the cotton crop.

Weed management approaches that rely on a limited number of tools often end up with uncontrolled weeds. The most common example of this is the repeated reliance on one or two groups of herbicides to control a target weed population. Within a weed population there is likely to be individual plants that are naturally resistant to any single herbicide. The frequency of these resistant individuals in the population is usually very low.

However, repeated exposure of the weed population to a limited range of herbicides results in these resistant individuals being selected out, so that eventually a large proportion of the population is resistant to the herbicides. Once herbicide resistance develops, the herbicide no longer controls the target weed. In addition, there may be cross-resistance to other herbicides in the same herbicide group, so that the weeds are resistant to all herbicides in the group, even though they have never been exposed to some of these herbicides.

As well as selecting for herbicide resistant weeds, the repeated use of a small number of weed management tools causes a species shift in the weed population. Weed species that are not controlled by these management tools soon come to dominate the weed population, and the weed spectrum shifts towards these weeds. This species shift can result in new weed problems, with weed species that are much more difficult to control than were the original weeds.

The risk of developing these problems can be greatly reduced by using an IWM program. An IWM program may be conceptualised as shown above (Figure 1), where all the individual components of the system contribute to a total weed management system.

## Why Use IWM?

Using an IWM program throughout the entire cotton rotation, including rotation crops and fallows, will:

- reduce the reliance on herbicides,
- reduce the risk of herbicide resistance developing in the weed spectrum and prolong the usefulness of the available herbicides,
- reduce the rate of shift in the weed spectrum towards more herbicide tolerant weeds,
- reduce the risk of herbicides accumulating in the soil and riverine systems, and
- reduce the total weed control costs in the future by reducing the weed seed bank (the number of weed seeds in the soil).

Although all these outcomes are important, the evolution of weeds resistance to glyphosate has become the number 1 weed threat to the cotton system, with a rapidly increasing range of glyphosate resistant grass and broadleaf weeds already present on many cotton properties. The presence of glyphosate resistant weeds is a serious threat to the conservation farming system and it is vital that growers address this issue before it is too late.

*Failure to prevent glyphosate resistant and tolerant weeds such as this feathertop Rhodes grass setting seed are a very real threat to the long-term viability of the cotton industry..*

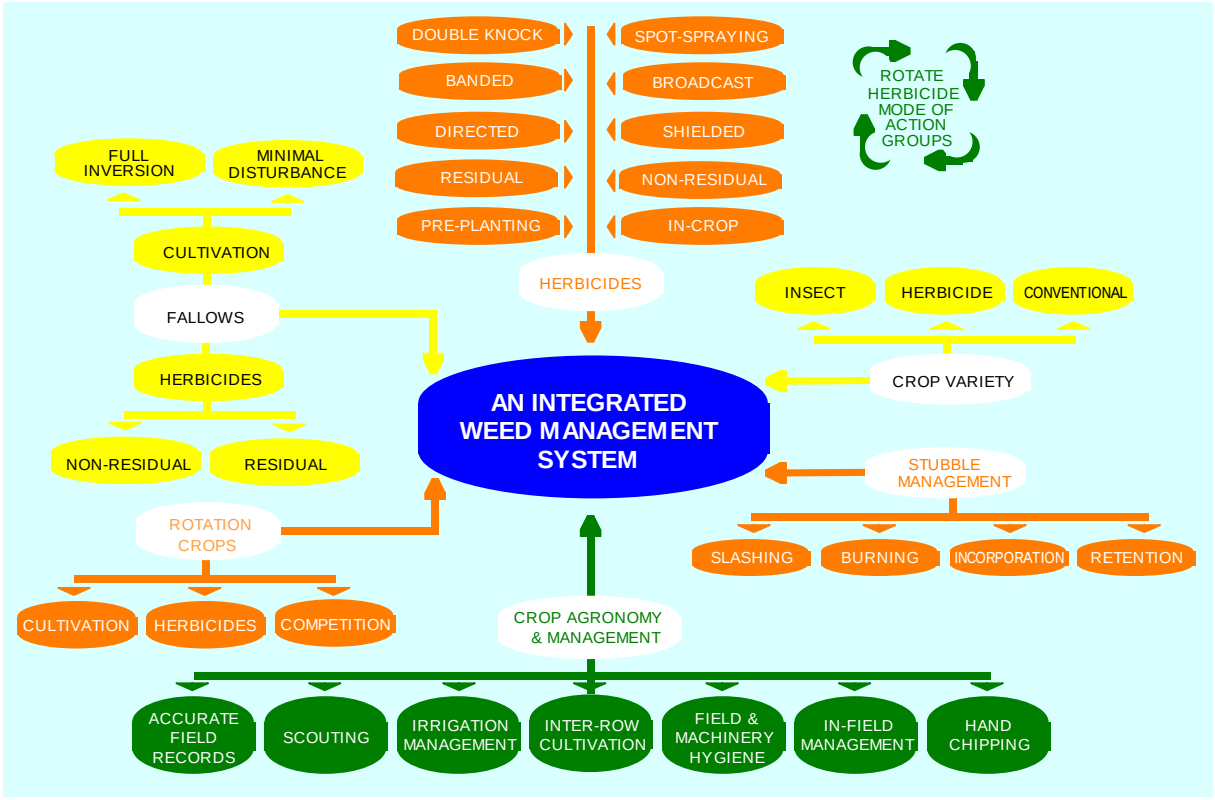



***Figure 1.*** *An integrated weed management system uses a large number of interrelated, complimentary components, so that the combination of the components achieves the best possible outcome.*

## Herbicide resistant weeds

In 2013 there were 220 weed species and 404 documented unique cases of weeds that have developed resistance to herbicides worldwide, with resistance identified in 60 different countries.

A total of 37 weed species have developed resistance to a range of herbicides in Australia, as shown in Table 1. Many of these weeds are cross-resistant to a range of herbicides. Cross-resistance occurs when a weed develops a mechanism of resistance to one herbicide that makes it resistant to other herbicides within the same or a different herbicide group.

For some of these weeds, such as ryegrass, there are individuals that have resistance to a large number of different herbicide groups, although any individual plant will not be resistant to every one of these herbicides. Nevertheless, there are instances of multiple resistance, with a single plant containing more than one resistance mechanism, making it resistant to more than one herbicide and herbicide mode of action group. Weeds with multiple resistance can be very difficult to control with herbicides.

Twenty four weed species have developed resistance to glyphosate around the world as shown in Table 2. Many more weeds can be expected to develop resistance to glyphosate if it continues to be the primary method of weed control in the farming system.

## Why we don't have herbicide resistant weeds in Australian cotton fields

We do!! Most cotton farms have glyphosate resistant flaxleaf fleabane and glyphosate resistant awnless barnyard grass. Many properties also have resistant annual ryegrass and resistant windmill grass. On top of this, the annual surveys show an ever increasing problem with species shift in the cotton system to glyphosate tolerant weeds such as Feathertop Rhodes grass, bindweed, rhyncho, emu foot and pigweed.

Adherence to the Crop Management Plan (managing glyphosate survivors) and the use of a combination of different weed control methods in Australian cotton fields has up to this point limited the appearance of resistant weeds as in-crop issues, but they are becoming increasingly common in the farming system. Cultivation and particularly hand hoeing have been excellent practices for preventing herbicide resistant survivors from setting seed and so preventing herbicide resistance building up. Complacency and continued over reliance on glyphosate for weed control will quickly change this situation.

***Table 1.*** *Important weeds that have developed resistance to herbicides in Australia.*

| Weed | Species | Herbicide mode of action | Herbicide Group | Examples[1] |
|---|---|---|---|---|
| Capeweed | *Arctotheca calendula* | Inhibitors of photosystem I | L | Spray.Seed |
| Wild oats | *Avena fatua* and *sterilis* | Inhibitors of acetyl coA carboxylase | A | Hoegrass |
| | | Inhibitors of acetolactate synthase | B | Hussar |
| | | Unknown | Z | Mataven |
| Wild turnip | *Brassica tournefortii* | Inhibitors of acetolactate synthase | B | Glean |
| Brome grass | *Bromus diandrus* and *rigidus* | Inhibitors of acetyl coA carboxylase | A | Nugrass |
| | | Inhibitors of acetolactate synthase | B | Monza |
| | | Inhibitors of photosystem II | C | simazine |
| | | Inhibitors of EPSP synthase | M | glyphosate |
| Windmill grass | *Chloris truncata* | Inhibitors of EPSP synthase | M | glyphosate |
| Flaxleaf fleabane | *Conyza bonarienses* | Inhibitors of EPSP synthase | M | glyphosate |
| Dirty dora | *Cyperus difformis* | Inhibitors of acetolactate synthase | B | Londax |
| Starfruit | *Damasonium minus* | Inhibitors of acetolactate synthase | B | Londax |
| Crabgrass | *Digitaria sanguinalis* | Inhibitors of acetyl coA carboxylase | A | Hoegrass |
| | | Inhibitors of acetolactate synthase | B | Glean |
| Sand rocket | *Diplotaxis tenuifolia* | Inhibitors of acetolactate synthase | B | Glean |
| Awnless barnyard grass | *Echinochloa colona* | Inhibitors of photosystem II | C | atrazine |
| | | Inhibitors of EPSP synthase | M | glyphosate |
| Paterson's curse | *Echium plantagineum* | Inhibitors of acetolactate synthase | B | Logran |
| Climbing buckwheat | *Fallopia convolvulus* | Inhibitors of acetolactate synthase | B | Glean |
| Dense flowered fumitory | *Fumaria densiflora* | Inhibitors of microtubule assembly | D | Trifluralin |
| Northern barley grass | *Hordeum glaucum* | Inhibitors of acetyl coA carboxylase | A | Hoegrass |
| | | Inhibitors of acetolactate synthase | B | Glean |
| | | Inhibitors of photosystem I | L | Spray.Seed |
| Barley grass | *Hordeum leporinum* | Inhibitors of acetyl coA carboxylase | A | Hoegrass |
| | | Inhibitors of photosystem I | L | Spray.Seed |
| Prickly lettuce | *Lactuca serriola* | Inhibitors of acetolactate synthase | B | Ally |
| Wimmera ryegrass | *Lolium rigidum* | Inhibitors of acetyl coA carboxylase | A | Hoegrass |
| | | Inhibitors of acetolactate synthase | B | Glean |
| | | Inhibitors of photosystem II | C | diuron |
| | | Inhibitors of microtubule assembly | D | trifluralin |
| | | Inhibitors of mitosis/microtubule organisation | E | Carbetamex |
| | | Inhibitors of fat synthesis | J | Avadex |
| | | Inhibitors of cell division/VLCFA | K | Dual |
| | | Inhibitors of EPSP synthase | M | glyphosate |
| | | Bleachers: inhibitors of carotenoid biosynthesis | Q | Director |
| Iceplant | *Mesembryanthemum* | Inhibitors of acetolactate synthase | B | Glean |
| Small square weed | *Mitracarpus hirtus* | Inhibitors of photosystem I | L | Spray.Seed |
| Serrated tussock | *Nassella trichotoma* | Inhibitors of fat synthesis | J | Taskforce |
| Calomba daisy | *Pentzia suffruticosa* | Inhibitors of acetolactate synthase | B | Glean |
| Paradoxa grass | *Phalaris paradoxa* | Inhibitors of acetyl coA carboxylase | A | Wildcat |
| Annual poa | *Poa annua* | Unknown | Z | Mataven |
| Wild radish | *Raphanus raphanistrum* | Inhibitors of acetolactate synthase | B | Glean |
| | | Inhibitors of photosystem II | C | atrazine |
| | | Bleachers: inhibitors of carotenoid biosynthesis | F | Brodal |
| | | Disruptors of plant cell growth | I | 2,4-D |
| Turnip weed | *Rapistrum rugosum* | Inhibitors of acetolactate synthase | B | Ally |
| Arrowhead | *Sagittaria montevidensis* | Inhibitors of acetolactate synthase | B | Glean |
| Charlock | *Sinapis arvensis* | Inhibitors of acetolactate synthase | B | Glean |
| Indian hedge mustard | *Sisymbrium orientale* | Inhibitors of acetolactate synthase | B | Glean |
| | | Bleachers: inhibitors of carotenoid biosynthesis | F | Brodal |
| | | Disruptors of plant cell growth | I | 2,4-D |
| African turnip weed | *Sisymbrium thellungii* | Inhibitors of acetolactate synthase | B | Glean |
| Common sowthistle | *Sonchus oleraceus* | Inhibitors of acetolactate synthase | B | Glean |
| Liverseed grass | *Urochloa panicoides* | Inhibitors of photosystem II | C | atrazine |
| | | Inhibitors of EPSP synthase | M | glyphosate |
| Dwarf nettle | *Urtica urens* | Inhibitors of photosystem II | C | atrazine |
| Squirrel-tailed fescue | *Vulpia bromoides* | Inhibitors of photosystem II | C | atrazine |
| | | Inhibitors of photosystem I | L | Spray.Seed |

*List compiled from Heap I.,The International Survey of Herbicide Resistant Weeds. Online. Internet.2013.*

*Note[1]. A complete list of product trade names is listed in the* ***Herbicide and formulation list,*** *section D1 in* ***WEEDpak.***

***Table 2.*** *Weeds that are resistant to glyphosate around the world (Group M).*

| Weed | Species | Country |
|---|---|---|
| Palmer amaranth | *Amaranthus palmeri* | USA |
| Needleburr | *Amaranthus spinosus* | USA (Mississippi) |
| Common waterhemp | *Amaranthus tuberculatus* | USA |
| Annual ragweed | *Ambrosia artemisiifolia* | Canada & USA |
| Giant ragweed | *Ambrosia trifida* | Canada & USA |
| Brome grass | *Bromus diandrus* | Australia (SA) |
| Windmill grass | *Chloris truncata* | Australia (NSW) |
| Flaxleaf fleabane | *Conyza bonariensis* | Australia, Brazil, Colombia, Greece, Israel, Portugal, South Africa, Spain & USA |
| Canadian fleabane | *Conyza canadensis* | Brazil, Canada, China, Czech Republic, Greece, Italy, Poland, Spain & USA |
| Tall fleabane | *Conyza sumatrensis* | Brazil, Greece, & Spain |
| Gramilla mansa | *Cynodon hirsutus* | Argentina |
| Sourgrass | *Digitaria insularis* | Brazil & Paraguay |
| Awnless barnyard grass | *Echinochloa colona* | Argentina, Australia & USA |
| Crowsfoot grass | *Eleusine indica* | Argentina, Chine, Colombia, Malaysia & USA |
| Summer cyprus | *Kochia scoparia* | Canada & USA |
| Tropical spangletop | *Leptochloa virgata* | Mexico |
| Italian ryegrass | *Lolium multiflorum* | Argentina, Brazil, Chile, New Zealand, Spain & USA |
| Perennial ryegrass | *Lolium perenne* | Argentina & New Zealand |
| Annual ryegrass | *Lolium rigidum* | Australia, France, Israel, Italy, South Africa, Spain & USA (California) |
| Parthenium | *Parthenium hysterophorus* | Colombia |
| Ribwort | *Plantago lanceolata* | South Africa |
| Winter grass | *Poa annua* | USA |
| Johnsongrass | *Sorghum halapense* | Argentina & USA |
| Liverseed grass | *Urochloa panicoides* | Australia (NSW) |

*Adapted from: Heap I.,The International Survey of Herbicide Resistant Weeds. Online. Internet.2013.*

## Choosing your farming future

Much of the US cotton industry has gone from being a "magic" industry a decade ago, where all weeds were cheaply controlled by a couple of in-crop applications of glyphosate, back to a "slave' industry, where weeds are king, demanding heavy inputs of expensive herbicides, inter-row cultivation and large amounts of hand-hoeing to manage them. In some instance, requiring levels of inputs that would make the Australian cotton industry economically unviable, with multiple herbicides, cultivation and hand-hoeing bills of over $1000/ha in Australian terms, just to produce a harvestable crop.

Now is the water-shed moment when Australian cotton growers get to choose their future. They can continue to enjoy the advantages of a glyphosate centred system and join the rest of the world on a down-hill spiral to out-of-control herbicide resistance and huge input costs. Or, they can walk away from the glyphosate centred system, returning to an integrated approach to weed management and a future with a full compliment of valuable herbicides.

Returning to an integrated weed management system doesn't necessarily mean going back to the full spectrum of conventional herbicides, inter-row cultivation and hand hoeing, but it does mean going away from a glyphosate centred approach in all aspects of the farming system and it means ensuring that any survivors of a glyphosate application are controlled using an alternative management tool before they set seed, in every part of the farming system, every time.

*A cotton field severely impacted by glyphosate resistant Palmer amaranth in the US. A field like this will require large inputs of herbicides, cultivation and hand-hoeing to produce a cotton crop next season. Photo: J. Norsworthy.*

## Components of Integrated Weed

## Management in cotton:

To develop an integrated approach to weed management, growers need to move away from relying on glyphosate to solve all weed issues and redevelop weed management systems that employ multiple management tools. Some of the tools they have available to them include:

1. **Scouting**
   Regularly check fields (cotton, rotations and fallows), roadways, channels, irrigation storages and unused land (grazing area, areas around sheds etc.) for weeds. Ensure that areas where herbicides are used are checked soon after application. Weeds which survive a herbicide must be controlled using an alternative tool before they set seed. Weeds may need to be closely examined, as some are capable of setting seed while still very small.

   Identify and closely monitor areas where machinery such as pickers and headers breakdown, as weed seeds are often inadvertently released when panels are removed from machines during repairs.

2. **Field records**
   Maintain records of crops and weed control methods, and effectiveness after each operation in each field, each year. This allows field rotations and the effectiveness of methods of weed control to be compared. In addition, fields with low weed pressure can be identified. Herbicide rates may be able to be reduced on these fields, and some herbicides may not be needed. Remember that glyphosate will be ineffective for controlling volunteer Roundup Ready Flex® cotton seedlings that may emerge on fallows, roadways, etc.

3. **Accurate weed identification**
   Ensure that weeds are correctly identified. Always be on the lookout for new weeds and if necessary seek help to get these identified.

4. **Follow label recommendations**
   No herbicide controls every weed. Ensure that the herbicide you use control the target weeds at the rates you are using.

   Most herbicide labels include information on surfactants, water rates, correct nozzles, nozzle pressure droplet size, etc. These are the parameters that will give the best result from the herbicide. Always follow the recommendations. Achieving a great result from a slow job with a high water rate makes much more sense than a quick but poor result from taking short cuts such as cutting the water rate.

   Always consider weather conditions and never spray when there is a risk of off-target movement.

5. **Timeliness of operations**
   Often the timeliness of a weed control operation has the largest single influence on the effectiveness of the operation. Herbicides are far more effective on rapidly growing weeds, and may be quite ineffective in controlling stressed weeds. Weeds must always be controlled before they set seed. Cultivation may be a more cost effective option than herbicides for controlling stressed weeds.

6. **Growing conditions**
   Herbicides are most effective in controlling small, rapidly growing weeds. Weeds that are larger than the recommended application window are unlikely to be controlled by the herbicide, even at the highest rate. Even going above label rates will not be effective for controlling most weeds, so if weeds are too big, look at other options, such as cultivation.

7. **Herbicide rates**
   Always use the recommended rate of a herbicide. Using lower than label rates leads to poor results and selects for non-target site resistance mechanisms. Using higher than label rates is wasteful, is more likely to cause off-target issues, generally will not improve weed control and creates very high selection pressure that leads to target site resistance. Doubling herbicide rates is not the answer to weeds that are too big or stressed!

8. **Herbicide combinations and rotations**
   Regular use of a small range of herbicides will result in a species shift to those weeds tolerant of the herbicides used. Using several herbicides in combination, or in rotation, can be an effective way of increasing the spectrum of weeds controlled. Always adjust herbicide rates when using combinations to reflect the overall amount of herbicide used. Always ensure that the herbicides are compatible before tank-mixing.

9. **Rotating herbicide groups**
   All herbicides are classified into groups, ranging from A to Z, based on their mode of action in killing weeds. The ratings are on the label and outside of each herbicide container. Weeds repeatedly exposed to herbicide groups A and B are at high risk of developing herbicide resistance. Groups C to Z have a moderate risk level, and resistant weeds already exist for many of these herbicide groups. Rotate herbicide groups whenever possible to avoid repeated resistance selection. If this is unavoidable, then other methods of weed control must be used in combination with the herbicides. Refer to Managing Herbicide Resistance in Cotton, section C1 in WEEDpak for more information.

### 10. Double knocking

The control of many of the more difficult to manage weeds can be improved by using the double knock strategy, applying a 2nd herbicide 7 – 14 days after the first herbicide. To be effective, the herbicides should have different modes of action and must both be applied at label rates that will kill the target weeds. Although this strategy is often employed to manage resistant weeds, it is not really effective once resistance has already occurred. Using cultivation as the 2nd knock is a valuable alternative practice, giving better levels of weed control than either herbicide or cultivation would alone.

### 11. Ensure optimum spraying conditions

There are a set of parameters to achieve the maximum on-target contact from a herbicide and minimise off-target movement (drift). These include:

- nozzles should be 0.5 m from the target,
- air movement should be between 3 and 15 km/h, and
- use as large a droplet size as practical.

Rushing around a paddock at high speed, with the booms flapping in the wind and using a low water volume that necessitates small droplets is a recipe for poor results. For more information on spray application refer to the Cotton Pest Management Guide.

### 12. Reducing herbicide use

Select fields with low weed pressure and reduce herbicide rates or remove some herbicide applications on these fields. Reducing the exposure of weeds to herbicides is one method of reducing the selection pressure on potentially herbicide resistant weeds. Limiting the use of residual herbicides will reduce the number of successive weed generations controlled by the same herbicide. Identify major weed species and use the herbicides most appropriate for these target weeds. Avoid blanket approaches without thinking about the weeds you are trying to control.

### 13. Herbicide tolerant cotton varieties

Consider using herbicide tolerant cotton varieties to reduce the need for some residual herbicides. Substituting post-emergent herbicides for some residual herbicides allows weed management to be more responsive, only controlling weeds when they are present. Follow the label crop management guidelines for herbicide tolerant cotton, ensuring that if weed escapes are detected, these weeds are controlled using an alternative tool before setting seed. **Herbicide resistance MUST be prevented**. Detailed information on the use of Roundup tolerant, Roundup Ready Flex cotton, is given in Monsanto's "Roundup Ready® Cotton technical Manual" and in Managing Roundup Ready Cotton, in WEEDpak.

### 14. Shielded spraying

Utilise shielded sprayers with non-selective herbicides, such as Spray.Seed® (a mixture of paraquat+diquat), to control herbicide tolerant weeds and reduce the need for hand hoeing and blanket herbicide applications. Weed detecting sprayers are available that can improve spray selectivity and can greatly reduce overall herbicide usage and cost, as well as reducing the risk of spray damage to the crop. This same technology can be used to great advantage in fallow spraying, making the strategic use of very high rates of two and three way herbicide mixes efficient and cost effective.

### 15. Spot spraying

Spot sprayers may be used as a cheaper alternative to hand hoeing for controlling low densities of weeds in crop. Ideally, weeds should be sprayed with a relatively high rate of a herbicide from a different herbicide group to the herbicides previously used to ensure that any herbicide resistant and herbicide tolerant weeds are still controlled.

### 16. Cultivation

Complete broad-acre cultivation is an effective, non-herbicide, weed control strategy in fallows. Ensure all weed escapes are controlled. Tactically use in-crop inter-row cultivation to control furrow weeds. Tractor guidance systems can improve the accuracy of cultivation next to the plant line. Cultivating when the soil is drying out is the most successful strategy for killing weeds and will reduce the damage caused by tractor compaction and soil smearing from tillage implements. Aggressive cultivation of dry soils can be effective for controlling perennial weeds

### 17. Hand hoeing

Hand hoeing is one of the most effective weed management tools for preventing the development of herbicide resistant weeds. Hand hoeing is ideally suited to dealing with low densities of weeds, especially those that occur within the crop row. However, it can be prohibitively expensive if used as a main form of weed control, and is normally used to supplement inter-row cultivation or spraying. Hand hoeing may be delayed until late in the season (before canopy closure) to reduce costs. This strategy relies on good scouting to ensure that weed escapes do not set seed

before they are controlled.

**18. Cropping rotations**

Strategically use rotations to help control weeds by selecting crops and/or fallows that enhance weed control in cotton. It may be useful to pick crops that allow different herbicides or methods of weed control.

Fallows provide opportunities to use different herbicide groups and non-herbicide methods of control.

**19. Farm hygiene**

Minimise new weeds entering fields. Clean down boots, vehicles, and equipment between fields and between properties. Pickers and headers are worthy of special attention. Eradicate any new weeds that appear while they are still in small patches; monitor frequently for new weeds. Weed patches should be monitored over a number of seasons, as weed seeds may remain dormant in the soil for many years.

Refer to **Managing Weeds with Farm Hygiene** in **WEEDpak** for additional information.

**20. Cotton variety selection**

Established cotton competes strongly with weeds, shading the soil surface and extracting water and nutrients from deeper in the soil profile than is available to emerging weeds. More vigorous, taller cotton varieties are better able to compete with weeds and better suited to weedy fields.

**21. Planting time**

Cotton seedlings grow slowly in cool spring conditions and do not compete well with weeds at this stage. Delaying planting on weedy fields until last, gives more opportunity to control weeds that emerge prior to planting and better conditions for cotton emergence and early growth.

**22. Irrigation management**

Weed emergence is often stimulated by rainfall and irrigation events. Irrigation should be planned to reduce the impact of weeds by coordinating irrigation with planting, cultivation and herbicide events. Pre-irrigation allows a flush of weeds to emerge and be controlled before cotton emergence. Irrigation during the season will cause another weed flush which will need to be controlled, but will also reduce moisture stress for existing weeds, making these more easily controlled by herbicide applications.

Irrigation must be sufficiently delayed after in-crop cultivation to allow all weeds to be killed by the cultivation, but should occur soon after cultivation to reduce stress to the crop.

**23. Crop competition**

An evenly established, vigorously growing cotton crop can compete strongly with weeds. Factors such as uneven establishment (gappy stands) and seedling diseases reduce crop vigour, and increase the susceptibility of the crop to competition from weeds. Close attention to crop agronomy will increase crop yields and can help reduce weed problems.

**24. Canopy closure**

Row closure in irrigated cotton is important to maximise light interception for optimum cotton yield but also provides a very important method of minimising light for weeds growing below the crop canopy. Many weeds will fail to germinate once row closure occurs, and many small weeds will not receive enough light to compete with cotton plants.

**25. Defoliation**

Additional opportunities for weed control can exist at defoliation where small numbers of large weeds, such as Noogoora burrs, emerge above the crop plants later in the season. If uncontrolled, these weeds can damage or block pickers and can reduce lint quality and contribute large numbers of seeds to the soil seed-bank. Hand removal of large weeds may be worthwhile. Alternatively, weeds can be controlled at defoliation with glyphosate or Spray.Seed (ground-rig application only). Drop-Ultra can also assist with defoliation and subsequent weed control.

**26. Consider the total management system**

Most inputs into cotton production have some impact on weed management and should be considered as part of the IWM program. Inputs such as fertilizer applications (type, amount, position and timing), stubble retention, and even insecticide applications all impact on weed growth and management. Remember, weeds and cotton are both plants.

**All inputs that affect cotton also affect weeds.**

Inputs such as in-furrow insecticides, fungicides and fertilizer placement can have a large impact on the early season vigour of cotton, which in turn affects its ability to compete with weeds

**27. Silver bullets**

There are no “silver” bullets for weed control. Glyphosate was the closest to a silver bullet to come along, and the silver is rapidly wearing off. It is now over 30 years since the last new herbicidal mode of action was discovered, and there is no reason to expect a new mode of action in the next decade. The critical thing is to keep the system as sustainable as possible, using a variety of weed management tools to ensure the longevity of every product.

## Herbicide Tolerant Crops – WARNING!

A range of herbicide tolerant crops is being developed throughout the world. Australia may see more of these crops over the next decade. Glyphosate and glufosinate tolerant cotton and canola varieteies are available and triazine and imazapic + imazapyr tolerant (Clearfield®) canola are already widely grown in Australia.

Whatever the technology, it is critical that growers adhere to the respective crop management plans and ensure that any survivors of a herbicide spray are controlled using an alternative technology before they can set seed.

**Always utilise the IWM principles when growing GM crops**.

*Best yields are achieved from well-managed cotton, free from weed competition.*

## Summary

Integrated Weed Management (IWM) is about managing weed problems now and reducing problems for the future.

The main principle behind IWM is to manage weeds by integrating different management tools together such that each tool compliments the others. In short, it is the principle of **NOT** relying on one method of weed control alone, particularly herbicides.

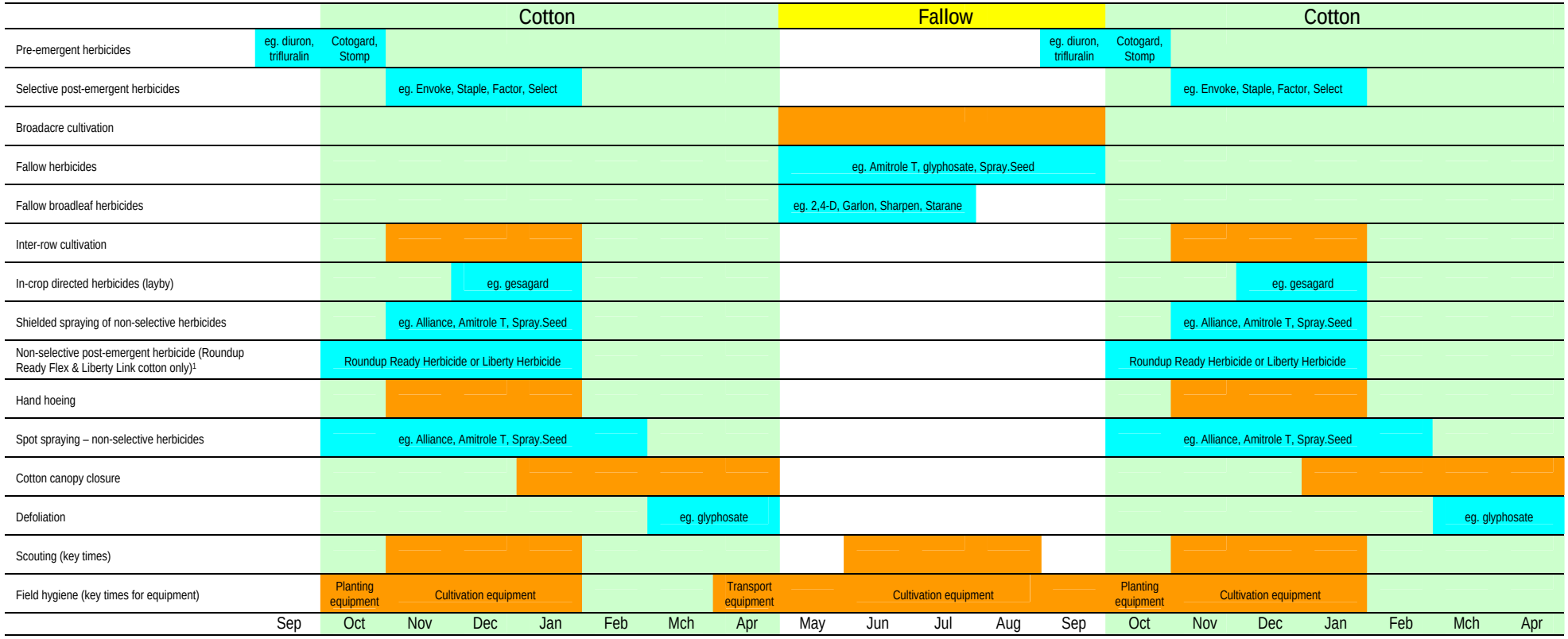
The three steps involved in implementing IWM are:

- **Education.** Understanding the principles of IWM, the range of control options available, and how to use them in an appropriate combination.
- **Evaluation.** Knowing the weed spectrum on each field and developing targeted economic and sustainable management strategies
- **Implementation.** Implementing an appropriate IWM strategy.

Preventing seed set and vegetative propagation is the most effective long-term method of managing and reducing weed problems. To develop an IWM program you need to think strategically about how you as a cotton grower can best utilise all available weed control methods in combination to give the best overall result, both in-crop and in rotations and fallows. Always avoid relying on one or two methods alone. Complacency with IWM may appear to save you money in the short term but will inevitably lead to expensive problems such as herbicide resistant weeds.

**IWM is best practice in weed management**

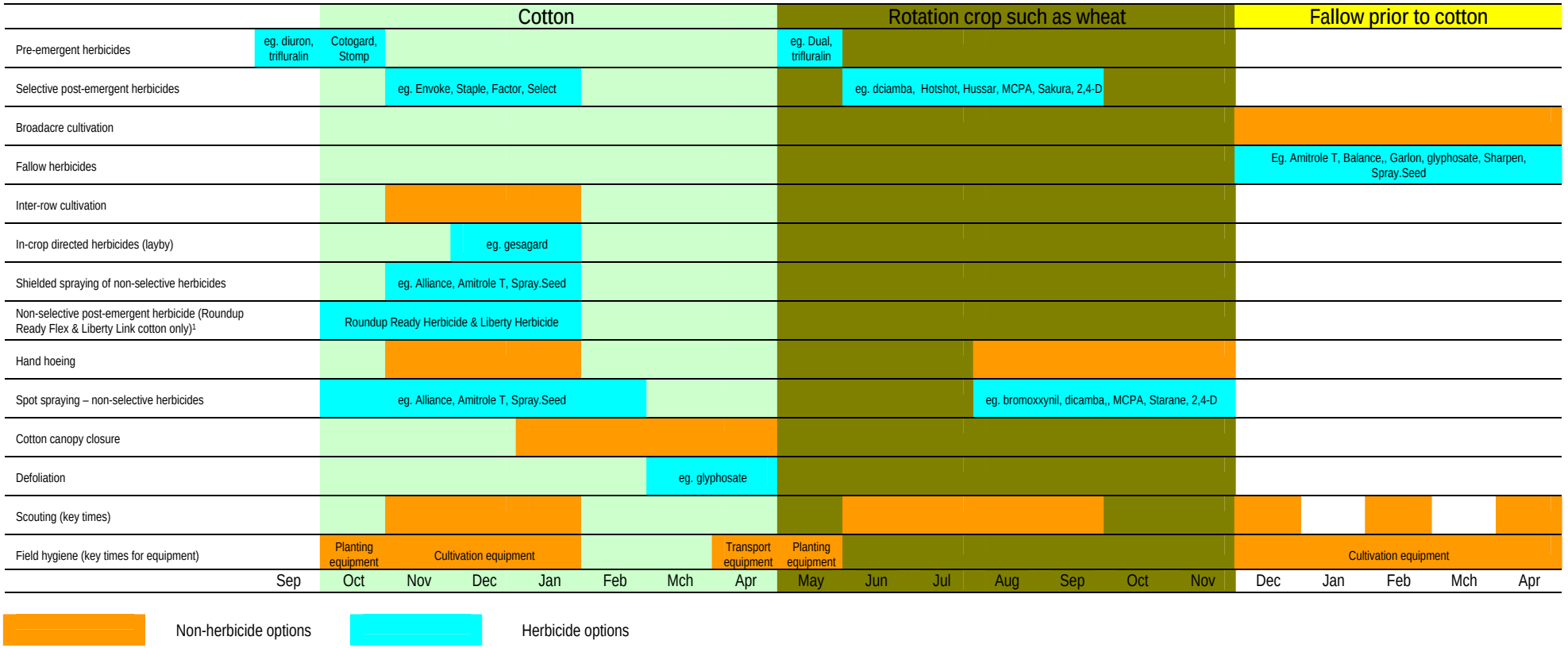
*Table 3. Integrated weed management calendar for back-to-back cotton. The timing of operations will vary between seasons and regions.*




Non-herbicide options  Herbicide options

*Note1. Roundup Ready Herbicide can only be safely used over-the-top of varieties including the Roundup Ready Flex trait, and Liberty Herbicide on varieties including the Liberty Link trait.*

*Table 4. Integrated weed management calendar for a cotton/rotation farming system. The timing of operations will vary between seasons and regions.*




*Note1. Roundup Ready Herbicide can only be safely used over-the-top of varieties including the Roundup Ready Flex trait, and Liberty Herbicide on varieties including the Liberty Link trait.*